PART 1

How to Mitigate the Most Common Collision Types and Circumstances

The purpose of this section of the Guidebook is to guide users to strategies and specific applications of the strategies based on the particular problems, collision types, or collision circumstances they are experiencing. Data regarding bus-and-pedestrian collisions were gathered from collision databases, from selected incident reports between 2003 and 2006, and from transit agencies and other stakeholders. Analysis of the collision data resulted in a number of collision circumstances that appear to account for the majority of all bus-and-pedestrian collisions.

The primary collision types and circumstances are shown in Table 1-1. The primary collision types are numbered (in no particular order) in the far left column. This numbering for collision type is important: it is used as a reference throughout this Guidebook. Then, for each collision type, the table shows the circumstances of the collision in terms of "bus action" and "pedestrian action." These actions depict what is happening just prior to the occurrence of each type of collision. Also noted in the table are the most likely points on the bus in which contact is made with the pedestrian for each collision type.

Throughout this Guidebook, the four primary types of collisions are defined in terms of the bus action, as shown in Table 1-1. These four collision types are (1) the bus turning right, (2) the bus turning left, (3) the bus pulling into a stop, and (4) the bus pulling away from a stop. Collision Types 1 and 4 have one or more variations of circumstances in terms of the pedestrian action. The collision circumstances, contributing factors, and associated mitigation strategies are discussed in more detail in this section of the Guidebook, as noted by the section number in the far right column of Table 1-1.

Of all the collision types, turns at intersections was the problem most frequently reported by transit agencies and other stakeholders, with left turns reported to be a problem more frequently than rights turns. Although turns were a common circumstance in the data, the data do not necessarily support the observation that turns are the most common problem. Of the incident reports reviewed, only 57 of these reports (34%) indicated that the bus was turning. However, amongst the 92 bus-and-pedestrian collisions that occurred at intersections, the data do show that 55 (60%) occurred when the bus was turning. The data also support the observation that, amongst the bus-and-pedestrian collisions that occurred while the bus was turning, left-turn collisions were more common than right-turn collisions: 69% involved a left turn, while 31% involved a right turn.

The other two collision circumstances most commonly cited by transit agencies and stakeholders were those occurring when the bus is either pulling into a stop or pulling away from a stop. Analysis of the incident data showed that 42 incidents (25%) occurred when the bus was at or near a bus stop. Of the 42 incidents that are known to have occurred at or near a bus stop, 23 (55%) involved a bus pulling into a stop, and 13 (31%) involved a vehicle pulling away from a stop.

Table 1-1. Most common collision types/circumstances (index table for Chapter 1).

Collision Type	Collision Circumstances			Point of Contact on Bus	Section
	Bus Action		Pedestrian Action		
1	Turning right…	at a green light	Crossing in parallel crosswalk	Front/front-right	1.1
			Waiting on curb or stepping into crosswalk	Rear-right	
		at a red light	Crossing in opposing crosswalk	Front	
2	Turning left		Crossing in parallel crosswalk	Front/front-right/ front-left	1.2
3	Pulling into a stop		Waiting at stop, crowding, or pushing	Front/front-right/mirror/door	1.3
4	Pulling away from a stop		Running next to bus	Right/rear-right/ rear duals	1.4
			Crossing in front of bus	Front/front-right/ front-left	

Another collision type that showed up in the collision data was when a bus was going straight and a pedestrian was struck. This collision circumstance is somewhat of an anomaly. Sixty-five (39%) of the bus-and-pedestrian incident records indicated that the bus was traveling straight when the collision occurred; however, this collision type was not frequently reported as a problem by transit agencies and stakeholders. Only a few agencies and stakeholders reported that they had experienced bus-and-pedestrian collisions when the bus was going straight, and the circumstances of these collisions varied. In some cases, pedestrians were hit mid-block, usually as a result of the pedestrian darting out from between parked cars. In other cases, pedestrians were hit crossing at intersections. Due to the differences across agencies in what and how much information was reported about the collisions, it was often times difficult to ascertain exactly what happened during the collisions. It is believed that at least some of the collisions in which the bus was reportedly going straight fall into one of the primary four collision types as just defined. For example, a bus pulling away from a stop that hits a pedestrian crossing in front of a bus could have been reported as going straight. Also, there were few strategies reported for specifically mitigating collisions in which the bus was going straight.

1.1 Collision Type 1: Bus Turning Right

Collision Type 1 occurs when a pedestrian is struck when a bus is turning right. Of the incident reports reviewed, 16 (10%) occurred when the bus was turning right. By far, the most frequently reported version of the right-turning collision is when the pedestrian is crossing in the parallel crosswalk and is struck by the front/front-right of the bus, as illustrated in Figure 1-1.

One variation of this collision type occurs when the bus, turning right, strikes a pedestrian who is waiting on the curb or who has just stepped from the curb into the roadway to begin crossing. In this case, the pedestrian is hit by the side of the bus near the rear. It should be noted that this particular variation was only reported as common by one transit agency and one stakeholder group.

Another variation of this collision type occurs when the bus is making a right-turn-on-red. In this case, the pedestrian is struck in the opposing crosswalk (the one perpendicular to the bus) with the front of the bus before the bus begins the turn.

Figure 1-1. Illustration of Collision Type 1—collision between pedestrian and right-turning bus.

While the location of the pedestrian varies, the circumstances of this collision type, its contributing factors, and mitigating strategies are quite similar regardless of the pedestrian position. These are discussed below.

1.1.1 Contributing Factors to Right-Turn Collisions with Pedestrians

This section presents and discusses a variety of factors that may contribute to right-turn collisions with pedestrians. The list is by no means exhaustive, and is presented here simply as a discussion of what appear to be the most probable contributing factors, based on the experience and expert opinions of the transit agencies and stakeholders who provided input to the development of this Guidebook.

1.1.1.1 Characteristics of Bus Turns

A key factor influencing the occurrence of right-turn collisions with pedestrians might be that pedestrians have difficulty recognizing that buses are about to turn. When buses turn, they pivot on the rear axle, moving forward and then sweeping an arc as the bus follows through the turn. At first glance, it may appear to a pedestrian that the bus is moving straight forward through the intersection when in fact the operator is initiating a right turn. Believing the bus is going straight, the pedestrian makes the decision to enter the crosswalk. Then, when the bus begins to move laterally into the right turn, the pedestrian is already in the roadway, setting up a situation in which a collision could occur.

1.1.1.2 Reduced Visibility of Pedestrians

There are a variety of reasons why pedestrians crossing in a crosswalk or standing at the curb may not be visible to a bus operator:

- Bus components—including the A-pillar, the farebox, and the side mirrors—might create blind spots, which obstruct the operator's view of a pedestrian.
- Visual obstructions outside of the bus such as posts, vendors, and signage may also block an operator's view of pedestrians.
- Various characteristics of pedestrians and the environment might make people more or less visible to a driver:
  - Someone who is small or slow-moving,
  - Someone who is wearing dark clothing, or
  - The absence or lack of adequate street or crosswalk lighting.

Often times when asked what happened following a bus-and-pedestrian collision, operators reported that they just did not see the pedestrian. The pedestrians seem to have come from "out of nowhere." This phenomenon is consistent with the visual cognition concept of "inattentional blindness" in which a person looks but does not see (*1*).

1.1.1.3 Failure to Scan

Failure of the operator to scan the crosswalk before initiating the turn can contribute to this type of collision. Even if the operator scans the crosswalk initially, failure to re-scan the crosswalks after initiating the right turn could lead to collisions with pedestrians in the crosswalk.

1.1.2 Strategies for Mitigating Right-Turn Collisions with Pedestrians

Table 1-2 presents strategies and specific applications of the strategies that have been implemented by one or more transit agencies or stakeholders. These applications could help mitigate

Table 1-2. Strategies for mitigating right-turn collisions with pedestrians.

Strategy	Application
Operator training	Instructional turning video
	Mirror adjustment training station
Operator outreach	"No trash on the dash" campaign
	"Watch for pedestrians" sticker on farebox
	Themed safety outreach slogans
Defensive driving techniques and policies	Operator moves in seat to see around obstructions
	Mandatory turning procedure
	Operator keeps eyes moving
	Slow down at intersections
	No right turn on red
Public outreach and education	Public outreach to schools
	Public outreach videos
Traffic engineering	Pedestrian scramble
	Pedestrian channelization
Bus mirror configuration and placement	Dual right-side mirrors
	Dual mirrors in single housing
	Smaller mirrors
Bus design/modification	Increased number of side marker lamps
	Blinking chevrons on right-side mirrors
	Audible turn signals
	Side strobe lights

right-turn collisions with pedestrians. For more detail on each application, refer to the corresponding section in Part 2.

In addition to the applications listed in Table 1-2, transit agencies and stakeholders provided suggestions that, in their opinions, might be ways to mitigate right-turn collisions with pedestrians. These suggestions included the following:

- Keep intersections and sidewalks clear of obstructions (such as heavy posts, signage, vendors, etc.) to improve the line of sight from the bus operator to pedestrians.
- Make crosswalks more noticeable through crosswalk enhancements (e.g., delineation, lighting) to enhance bus operators' expectations about the presence of pedestrians.
- Use split mirrors (with the convex mirror on top), larger convex mirrors, and mirrors in which the height could be adjusted (either manually or electronically).
- Install tactile strips on the edges of sidewalks to keep pedestrians away from the edge of the roadway after consulting ADA standards and guidelines.
- Implement public education and outreach campaigns to educate pedestrians about important issues such as watching for turning buses while crossing, keeping back from the edge of the roadway when waiting to cross, and the mechanics of a turning bus.

1.2 Collision Type 2: Bus Turning Left

Collision Type 2 occurs when a pedestrian is crossing the street in the crosswalk and a bus operator is making a permitted left turn onto the street that the pedestrian is crossing, as illustrated in Figure 1-2. Of the incident reports reviewed, 36 (22%) occurred when the bus was turning left.

This potential conflict between a pedestrian and a left-turning vehicle is intrinsic to many signalized intersections with pedestrian signals. This is because the pedestrian WALK phase occurs simultaneously with the permitted left turn phase for traffic (i.e., green ball). When there is a

Figure 1-2. Illustration of Collision Type 2—collision between pedestrian and left-turning bus.

protected left-turn phase for traffic (i.e., green arrow), the corresponding pedestrian signal will read DON'T WALK or will show a solid orange hand, thereby separating the movements and eliminating potential conflicts between left-turning vehicles and pedestrians by prohibiting pedestrians from crossing. In many locations, however, even when there is a protected left-turn phase, it is followed by a time when vehicles are allowed to make permitted left turns. Here, the left-turning vehicles must yield to oncoming traffic, as well as to pedestrians in the crosswalk.

1.2.1 Contributing Factors to Left-Turn Collisions with Pedestrians

This section presents and discusses a variety of factors that may contribute to left-turn collisions with pedestrians. The list is by no means exhaustive and is presented here simply as a discussion of what appear to be the most probable contributing factors, based on the experience and expert opinions of the transit agencies and stakeholders who provided input to the development of this Guidebook.

1.2.1.1 Characteristics of Bus Turns

A key factor influencing the occurrence of left-turn collisions with pedestrians might be that pedestrians have difficulty recognizing that buses are about to turn. When buses turn, they pivot on the rear axle, moving forward and then sweeping an arc as the bus follows through the turn. At first glance, it may appear to a pedestrian that the bus is moving straight forward through the intersection when in fact the operator is initiating a left turn. Believing the bus is going straight, the pedestrian makes the decision to enter the crosswalk. Then, when the bus begins to move laterally into the left turn, the pedestrian is already in the roadway, setting up a situation in which a collision could occur.

1.2.1.2 Reduced Visibility of Pedestrians

There are a variety of reasons why pedestrians crossing in a crosswalk or standing at the curb may not be visible to a bus operator:

- Bus components—such as the A-pillar and the side mirrors—might create blind spots, which obstruct the operator's view of a pedestrian.
- Visual obstructions outside of the bus such as posts, vendors, and signage may also block an operator's view of pedestrians.
- Various characteristics of pedestrians and the environment might make people more or less visible to a driver:
  - Someone who is small or slow-moving,
  - Someone who is wearing dark clothing, or
  - The absence or lack of adequate street or crosswalk lighting

Often times when asked what happened following a bus-and-pedestrian collision, operators reported that they just did not see the pedestrian. The pedestrians seem to have come from "out of nowhere." This phenomenon is consistent with the visual cognition concept of "inattentional blindness" in which a person looks but does not see (*1*).

1.2.1.3 Failure to Scan

Failure of the operator to scan the crosswalk before initiating the left turn can contribute to this type of collision. Even if the operator scans the crosswalk initially, failure to re-scan the crosswalks after initiating the left turn could lead to collisions with pedestrians in the crosswalk.

1.2.1.4 Attention to Opposing Vehicular Traffic

A unique characteristic of this collision type is that bus operators not only have to scan for pedestrians in the crosswalk before turning, but they also must watch for a gap in oncoming traffic before

turning. It was suggested that in some cases, the operator focuses so heavily on the oncoming traffic that not enough attention is paid to pedestrians. One stakeholder specifically reported that the combination of operators hurrying to keep schedule and waiting for a gap in both vehicle and pedestrian traffic causes them to lose sight of pedestrians.

1.2.2 Strategies for Mitigating Left-Turn Collisions with Pedestrians

Table 1-3 presents strategies and specific applications of the strategies that have been implemented by one or more transit agencies or stakeholders. These applications could help mitigate left-turn collisions with pedestrians. For more detail on each application, refer to the corresponding section in Part 2.

In addition to the applications listed in Table 1-3, transit agencies and stakeholders provided suggestions that, in their opinions, might be ways to mitigate left-turn collisions with pedestrians. These suggestions included

- Keep intersections and sidewalks clear of obstructions to improve the line of sight from the bus operator to pedestrians.
- Make crosswalks more noticeable to enhance bus operators' expectations about the presence of pedestrians.
- Reduce in-bus obstructions related to mirrors and the A-pillar.

1.3 Collision Type 3: Bus Pulling into Bus Stops

Collision Type 3 occurs when a bus is pulling into a bus stop and a pedestrian is struck. Of the incident reports reviewed, 25 (15%) occurred when the bus was pulling into a bus stop. When

Table 1-3. Strategies for mitigating left-turn collisions with pedestrians.

Strategy	Application
Operator training	Instructional turning video
	Mirror adjustment training station
Operator outreach	"No trash on the dash" campaign
	"Watch for pedestrians" decals on telephone/radio handsets
	Themed safety outreach slogans
Defensive driving techniques and policies	Operator moves in seat to see around obstructions
	Mandatory turning procedure
	Square left turns
	Operator keeps eyes moving
	Slow down at intersections
Public outreach and education	Public outreach to schools
Traffic engineering	Protected left-turn signal
	Pedestrian scramble
Bus mirror configuration and placement	Dual left-side mirrors placed lower on bus
	Dual mirrors in single housing
	Standardized left-side mirror height
	Smaller mirrors
Bus design/modification	Increased number of side marker lamps
	Blinking chevrons on left-side mirrors
	Audible turn signals
	Side strobe lights

the bus is pulling into a bus stop, the pedestrian's location and behavior varies: he or she might be waiting at the stop, crossing the road and arriving at the stop, or walking along the road or sidewalk near the stop. Figure 1-3 illustrates an example of this collision type.

1.3.1 Contributing Factors to Collisions with Pedestrians When Pulling into Bus Stops

This section presents and discusses a variety of factors that may contribute to collisions with pedestrians when buses are pulling into bus stops. The list is by no means exhaustive and is presented here simply as a discussion of what appear to be the most probable contributing factors, based on the experience and expert opinions of the transit agencies and stakeholders who provided input to the development of this Guidebook.

1.3.1.1 Crowded Bus Stop Locations

The primary contributing factor reported for collisions with pedestrians when pulling into bus stops was crowded bus stops due to

- A large demand for the bus,
- Limited sidewalk space, and
- Sidewalk obstacles.

Crowded bus stop locations can lead to various problems, including

- Pedestrians standing too close to the roadway as the bus arrives at the stop,
- Pedestrians pushing as the bus arrives at the stop, or
- Conflicts between intending passengers and passing pedestrians.

All of these situations can result in a pedestrian accidentally making contact with a bus in or near the roadway as the bus is pulling into the stop.

Figure 1-3. Illustration of Collision Type 3—collision between pedestrian and bus pulling into bus stop.

1.3.1.2 Lack of Visibility of Pedestrians at Bus Stops

Lack of visibility of pedestrians at bus stops is a problem that can be caused by a number of issues including

- Limited or no lighting, and
- Obstructions (e.g., wide columns, traffic signals, and signs) limiting an operator's view of pedestrians.

1.3.1.3 Bus Stop Placement

The location of a bus stop relative to the roadway may play a role in some collisions when buses are pulling into a bus stop:

- A bus stop that is located too close to the roadway provides no positive separation between pedestrians and passing vehicles.
- A bus stop that is set back too far from the roadway for the pedestrian to be seen by an approaching bus operator may lead the pedestrian to encroach into the roadway to be more visible.

1.3.2 Strategies for Mitigating Collision with Pedestrians When Pulling into Bus Stops

Table 1-4 presents strategies and specific applications of the strategies that have been implemented by one or more transit agencies or stakeholders. These applications could help mitigate collisions with pedestrians when buses are pulling into bus stops. For more detail on each application, refer to the corresponding section in Part 2.

In addition to the strategies listed in Table 1-4, transit agencies and stakeholders provided suggestions that, in their opinions, might be ways to mitigate collisions with pedestrians when buses are pulling into bus stops. Most of these strategies included creating "safe zones" for pedestrians. These suggestions included the following:

Table 1-4. Strategies for mitigating collisions with pedestrians when pulling into bus stops.

Strategy	Application
Operator outreach	"No trash on the dash" campaign
Defensive driving techniques and policies	Operator moves in seat to see around obstructions
	Operator keeps eyes moving
Public outreach and education	Stay alert around buses and trains campaign
Roadway design	Bulb-outs
Bus mirror configuration and placement	Dual mirrors in single housing
	Smaller mirrors
Bus design/modification	Side strobe lights
Bus stop location planning and bus stop design	Monitoring, relocation, and removal of bus stops
	Bollards, barriers, and striping
	Standee lines at bus stops
Bus stop lighting and illumination	Retro-reflective paddles
	Flashing beacons
	Retro-reflective bus stop signs
	Solar-powered shelter lights
	Pocket and pen lights

- Install pedestrian channelization to funnel pedestrians to safe and visible locations in which to wait for the bus.
- Install pedestrian channelization at crowded stops to prevent pedestrians from falling or being pushed into the roadway when a bus is pulling into the stop.
- Install bus nubs to give pedestrians a place to wait for the bus and to make them more visible to operators.
- After consulting ADA standards and guidelines, install tactile strips at curbs to keep pedestrians from standing too close to the roadway.
- Install painted bus "pads" to delineate where a bus will stop and where passengers should wait.
- Use video supervision at bus stops where pedestrians crowding, pushing, or roughhousing is known to be a problem.
- Keep sidewalks and bus stops free from obstructions to improve an operator's line of sight to pedestrians and to reduce objects that pedestrians can run into or trip over.

1.4 Collision Type 4: Bus Pulling Away from Bus Stops

Collision Type 4 occurs when a bus is pulling away from a bus stop and a pedestrian is struck. Of the incident reports reviewed, 16 (10%) occurred when the bus was pulling away from a stop.

By far the most common circumstance of this collision is when a pedestrian is running after the bus after it has already pulled away from the curb and the pedestrian, who is running alongside the bus, trips and falls under the bus (Figure 1-4). However, a few stakeholders reported a variation of this collision type, which involves a pedestrian crossing the roadway in front of the bus as the bus is pulling away from the curb (Figure 1-5).

1.4.1 Contributing Factors to Collisions with Pedestrians When Pulling Away from Bus Stops

This section presents and discusses a variety of factors that may contribute to collisions with pedestrians when buses are pulling away from bus stops. The list is by no means exhaustive and is presented here simply as a discussion of what appear to be the most probable contributing factors, based on the experience and expert opinions of the transit agencies and stakeholders who provided input to the development of this Guidebook.

Figure 1-4. Illustration of Collision Type 4—collision with pedestrian running alongside bus when pulling away from a bus stop.

Figure 1-5. Illustration of Collision Type 4—collision with pedestrian crossing in front of bus when pulling away from a bus stop.

1.4.1.1 Pedestrians Chasing Buses

One causative factor for this collision type is pedestrians chasing buses after they have left the bus stop. Pedestrians are often times running late, rushing, and unwilling to wait for the next bus. When pedestrians chase after buses, they are usually trying to get the bus operator's attention and will sometimes even tap on the side of the bus.

1.4.1.2 Lack of Information about Bus Arrivals

In some cases, pedestrians may choose to run after a bus because they are unaware of when the next bus will arrive (they may not be familiar with the schedule, they may think the next bus will be running behind schedule, etc.).

1.4.1.3 Visibility of Pedestrians at Bus Stop

Sometimes, this collision type is influenced by the difficulty of seeing pedestrians along the side of the road, especially at night. This could be because of the poor design of the bus stop or roadway influencing overall visibility of pedestrians, including poor bus stop location relative to the edge of the roadway and overall visibility of pedestrians.

1.4.1.4 Attention to Vehicular Traffic

At some bus stop locations, bus operators must merge into the traffic when departing a stop. In the case of some collisions, it is possible that the operator focuses on finding a gap in traffic, and not enough attention is paid to pedestrians who are approaching the bus along the right side.

1.4.1.5 Sidewalk Obstacles and Maintenance

When pedestrians are running for the bus, objects in the bus stop area (such as trash dispensers and signs) become obstacles that when hit, can "push" pedestrians into the roadway. Likewise, poorly maintained sidewalks (e.g., uneven sidewalks, cracks) can cause pedestrians to trip and fall, especially when pedestrians are chasing a bus.

Table 1-5. Strategies for mitigating collisions with pedestrians when pulling away from bus stops

Strategy	Application
Operator training	Service stop exit procedure
	No stopping after closing door
Public outreach and education	Bus safety campaign
	Pamphlets about not running after the bus
Bus mirror configuration and placement	Right convex mirror(s)
	Larger, wider mirrors mounted higher
Bus design/modification	Bus curb lights
	S1-GARD
Bus stop location planning and bus stop design	Far-side bus stops
	Bollards, barriers, and striping

1.4.2 Strategies for Mitigating Collisions with Pedestrians When Pulling Away from Bus Stops

Table 1-5 presents strategies and applications of the strategies that have been implemented by one or more transit agencies or stakeholders. These applications could help mitigate collisions with pedestrians when pulling away from bus stops. For more detail on each application, refer to the corresponding section in Part 2.

In addition to the strategies listed in Table 1-5, transit agencies and stakeholders provided suggestions that, in their opinions, might be ways to mitigate collisions with pedestrians when pulling away from bus stops. These suggestions included the following:

- Through public outreach campaigns, educate pedestrians about the specific dangers of running after buses.
- Install tactile strips on the sidewalk to keep pedestrians from running too close to the roadway.
- Maintain sidewalks and keep them free of obstructions.
- Install route number displays on the back of buses to provide information to riders that might stop them from running after a bus. An intending passenger may run after a bus thinking it is theirs, when it actually is not. Route number displays on the back of buses could help in this situation.
- Install route number displays and countdown timers on the back of buses to provide information to riders that might stop them from running after a bus. An intending passenger may run after a bus not knowing when the next bus will arrive, when in fact, the next bus may be only a few minutes away. Countdown times, displaying real-time bus arrival information could help in this situation. (It should be noted that real-time bus arrival information in some cases might also encourage pedestrians to run after the bus if they realize the next bus isn't for some time.)